Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

STUDIES OF NATURAL AND ARTIFICIAL PARTHENOGENESIS IN THE GENUS NICOTIANA.[1]

RICHARD WELLINGTON

ASSOCIATE HORTICULTURIST, NEW YORK AGRICULTURAL EXPERIMENT STATION

PARTHENOGENESIS is a phenomenon that is known to exist in many widely separated genera of the higher plants. In but few cases does it seem likely that the regular reduction of gametogenesis with the subsequent nuclear fusion of fertilization never occurs, yet it is probable—from the frequent discovery of new examples—that it will ultimately be found that the ability to dispense with typical sexual reproduction is comparatively common. Should this prove to be the case, one would be forced to conclude that sexual reproduction was developed for reasons other than protoplasmic necessity, as Maupas and his followers would have biologists believe.

This is the fundamental problem toward the solution of which all data on parthenogenesis contribute, but pending the time when it can be discussed intelligently, there are sub-questions that are not without their interest. Loeb's researches have shown that the stimulus to development which is an attendant result of fertilization, is physico-chemical. Observations on several genera of parthenogenetic insects have shown that the presence or absence of sexual reproduction is largely dependent upon external conditions such as food, light, temperature, etc. Little is known of the rôle played by such stimuli in parthenogenesis in plants, however, although knowledge on the subject is of some import aside from theory. For example, the geneticist is concerned, if, under any of the conditions likely to obtain in his experiments, plants ordinarily reproducing sexually should be incited to reproduce parthenogenetically.

---

[1] Contribution from the Laboratory of Genetics, Bussey Institution of Harvard University.

This paper describes some facts on the subject obtained by experiments on the genus *Nicotiana*.

THE MATERIAL.

The material used in the investigation was turned over to me by Professor E. M. East, who had received it from various parts of the world. Each species had been cultivated in pure lines for at least three generations, so that it may be considered to be fairly well known. The specific names used are those accepted by Comes in his "Monographie du genre Nicotiana," Naples, 1899. To his descriptions, and to such figures as are published in the *Botanical Magazine,* the plants corresponded perfectly. To all intents and purposes, therefore, the plants may be considered wild, although they have been under cultivation several years.

The writer desires to express his thanks to Professor East, under whose direction the investigation was carried out, for the use of the pedigreed material and for much valuable advice. Certain unpublished data obtained in his own researches on *Nicotiana* are incorporated with his consent.

HISTORICAL.

For historical purposes it is only necessary to give a brief review of Hans Winkler's paper, "Über Parthenogenesis und Apogamie im Pflanzenreiche," published in 1908; and the less comprehensive paper, "Parthénogénèse des Végétaux Supérieurs," of L. Blaringhem, published in 1909. Blaringhem in his historical account of this subject, states:

> Déja Camerarius dans sa lettre célèbre sur le sexe des plantes (*De sexu plantarum epistola,* 1694) reconnaît que dans ses essais de castration du Maïs il obtient, malgré l'absence de pollen, le développement de graines fertiles sur les épis latéreaux femelles.

Among the early observers of parthenogenetic[2] qualities in plants are given Spallanzani (1767–1779), Henschel (1817–1818), Lecoq (1827), Girou de Buzareinques (1827–1833), Ramisch (1833–1838), Bernhardi (1834–1839), Tenore (1854), Gasparini (1846) and Naudin (1856). As a few of the plants cited by these authors are at the present time the object of research, Blaringhem gives a list of the observed plants with an indication of the more doubtful.

The list is given as follows:

(*a*) Plantes Dioiques.
  Bryonia dioïca d'après Naudin (confirmé en 1904 par Bitter),
  Cannabis sativa d'après Camerarius, Spallanzani, Henschel, Girou de Buzareinques, Berhardi et Naudin,
  Datisca cannabina d'après Wenderoth et Fresenius (très douteux),
  Lychnis dioïca d'après Henschel et Girou de Buzareinques,
  Mercurialis annua d'après Lecoq, Ramisch, Naudin et Thuret,
  Pistacia narbonensis d'après Bocconi et Tenore,
  Spinacia oleracea d'après Spallanzani, Lecoq et Girou de Buzareinques.
(*b*) Plantes Monoiques.
  Cucurbita Melopepo, C. Citrullus et autres espèces d'après Spallanzani, Sageret et Henschel,
  Ficus Carica d'après Gasparini,
  Urtica pilulifera d'après Henschel (très douteux).

Winkler, in his introduction, cites *Cælebogyne ilicifolia* J. Smith, a diœcius member of the Euphorbiaceæ native to eastern Australia, which had been cultivated since 1829 at Kew in three "weiblichen Stocken," as the first mentioned case of seed production without the assistance of pollen grains. This observation led Smith to believe that pollen is not essential for the perfecting of Euphorbiaceæ seed. In 1857 A. Braun described *Chara crinita* Wallr. as a true case of parthenogenesis. In 1877, Strasburger with the aid of modern technique found that the embryos in *Cælebogyne ilicifolia* were formed without fertilization, but that parthenogenesis was absent, as the embryos came not from unfertilized eggs, but from adventitious growths (Sprossungen) of the nucellus tissue. In 1900, Juel definitely proved its existence in *Antennaria,* thus establishing its presence in the higher plants.

---

[2] No doubt many of these observations were incorrect, owing to imperfect control.

As botanical investigators do not always agree in the use of the terms parthenogenesis and apogamy, Winkler divides all reproductive phenomena into three divisions, namely: Amphimixis, Pseudomixis, and Apomixis.

1. Amphimixis, which designates the normal sexual process.

2. Pseudomixis, which means the replacement of true sex-cell fusions by a false sexual process. Pseudomixis thus differs from amphimixis, essentially, only in the circumstance that the fusing cells are not differentiated as gametes. As an example of the pseudomictic (pseudomiktische) method of reproduction is cited *Lastrea pseudomas* var. *polydactyla* Wills, in which the sporophyte arises from a prothallium cell, its primordial nucleus fusing with a nucleus from a neighboring cell. Farmer and Digby (1907, p. 191) name this procedure "pseudoapogamy." All non-sexual nuclear or cell fusions must not be considered as pseudosexual, however, for there is an asexual cell fusion in addition to the sexual and the pseudosexual, as, for example, the nucleus fusion described by Nemec (1902, 1903) in chloralized roots of *Vicia,* and also the frequently mentioned nucleus fusion in the young ascus of the Ascomycetes.

3. Apomixis, which is the replacement of sexual reproduction by another, an asexual process, which is not bound up with nuclear fusions. For it, there is already another term, namely that of apogamy. This latter term was applied by de Bary (1878, p. 479) for the fact, "dass

einer Species (oder Varietät) die sexuelle Zeugung verloren geht und durch einen anderen Reproduktionsprocess ersetzt wird." The word apogamy used with the meaning intended by de Bary covers the term apomixis of Winkler; but as all the recent authors use the expression apogamy in a new sense, the introduction of a new term seems justifiable.

Apomixis is subdivided into vegetative propagation, apogamy, and parthenogenesis:

(*A*) Vegetative propagation consists of the replacement of fertilization by vegetative formations (Ausläuferbildungen), arising of leafy (blattbürtiger) shoots, vivipary and similar examples of simple vegetative division and the adventitious embryo formation from nucellus cells.

(*B*) Apogamy, the origin through apomixis of a sporophyte out of vegetative cells of the gametophyte, is subdivided into (*a*) somatic apogamy, if the cell or the cell complex which produces the sporophyte possesses the diploid chromosome number, and (*b*) generative apogamy, if the mother cells of the sporophyte carry only the haploid chromosome number.

(*C*) Parthenogenesis, the apomictic origin of a sporophyte from an egg, is subdivided into (*a*) somatic parthenogenesis, if the egg possesses a nucleus with the diploid or unreduced chromosome number, and (*b*) generative parthenogenesis, if the nucleus of the egg is provided with only the haploid number of chromosomes.

Winkler remarks, it is probable that the relations between somatic apogamy and apospory are very close, as the former without the latter is surely not thinkable, while the latter (the primary proceeding) may exist without somatic apogamy. Examples of somatic apogamy are given, but no certain cases of generative apogamy are known; nevertheless, Winkler is very certain that their existence is possible.

Somatic parthenogenesis can be obtained in two ways: first, it can combine with apospory, that is, a normal sporophyte cell with the diploid number of chromosomes can grow directly into the gametophyte; second, the gametophyte can arise from the spores in the usual manner, except that the reduction division is discontinued. Examples are known for both cases. After discussing the cell division of the more interesting cases of somatic parthenogenesis, he sums up the families in which it occurs, as follows:

1. Polypodiaceæ (*Athyrium Filix-fœmina* var. *clarissima* Bolton and var. *unco-glomeratum* Stansfield; *Scolopendrium vulgare* var. *crispum Drummondæ*).
2. Marsiliaceæ (*Marsilia Drummondii* R. Br.).
3. Ranunculaceæ (*Thalictrum purpurascens, Th. Fendleri*).
4. Rosaceæ (*Alchimilla* § *Eualchimilla*).
5. Thymelæaceæ (*Wikstroemia indica*).
6. Compositæ (*Antennaria alpina, A. fallax, A. neodioica; Taraxacum; Hieracium* § *Archieracium* and § *Pilosella*, almost completely).

According to Juel (1900, 1904), Murbeck (1901), Guérin (1904) and Strasburger (1904, 1907), somatic parthenogenesis is simply a vegetative process, the egg being merely an ovate-shaped body cell of the sporophyte. Winkler disagrees with this opinion, for if it be true, the female individuals of parthenogenetic plants could produce only female offspring. But this is not the case, for from parthenogenetic seed of *Thalictrum Fendleri,* Day obtained seeds which yielded abundantly staminate and pistillate plants. Thus, it is conclusively proven that cells are not always equivalent, even though they are physiologically and morphologically alike.

Two theoretical cases of generative parthenogenesis are given as thinkable; first, the whole cycle of development could occur without a change in the number of chromosomes, that is, the haploid number is retained throughout; second, a regenerative doubling of the chromosomes could appear in the development of an egg with the haploid number into the sporophyte. No examples of the latter are known to occur in the plant kingdom.

Merogany (Merogonie) is given a brief notice. This expression was first used by Delage (1899), for the successful fertilization of a denucleated fragment of an egg by a spermatozoon. It was established in animals by O. and R. Hertwig (1887) and Boveri (1889) and in the plant *Cystosira barbata* by Winkler (1901).

Parthenocarpy is more fully discussed, as it has much in common with both parthenogenesis and apogamy, and is a great source of danger in investigations made to determine their presence or absence. Noll (1902) introduced the term, and defined it as the capacity of many plants, under exclusion of pollen, to form fruits outwardly normal, but in which seeds are absent or aborted. This condition was discovered by the elder Gärtner (1788) who named it "*frutificatio spuria*" and was for the first time critically investigated by the younger Gärtner (1844), who called it "Fruchtungsvermögen." Winkler thinks that it might be possible to separate the cases of stimulative parthenocarpy, in which the seedless fruits are produced only after pollination with their own or foreign pollen or in consequence of an insect prick or some other irritation; and the cases of vegetative parthenocarpy, in which the seedless fruits are formed without any pollination or other outer irritation. The latter phenomenon is thought to occur less frequently than the former. Noll in 1902 described it in the cucumber (Gurke) and mentioned the then known cases, the fig and the seedless medlar. Ewert[3] has found that several kinds of fruit can develop without the assistance of pollen. The best results were obtained when all the blossoms of an individual plant were protected from fertilization, as otherwise the fertilized flowers were so markedly favored in their development when compared with the remaining unfertilized ones, that the latter dropped while immature.

---

[3] Ewert (1909, 1911) has noted the presence of parthenocarpy in the apple, pear, grape and gooseberry, and Kirschner (1900) has noted the same in the quince.

The relation between parthenocarpy and parthenogenesis of higher plants is very close, as all the known cases of parthenogenesis are associated with parthenocarpy, for not only embryos and seeds, but fruits develop at the same time without fertilization. Since both fruits and seeds which appear perfectly normal will develop, although they are without embryos, one can not be positive about parthenogenesis unless the presence of the embryo is ascertained.

In the discussion on the causes of parthenogenesis and apogamy, Winkler suggests the possibility of physico-chemical changes operating in a flower in consequence of non-pollination, and causing the parthenogenetic development of the ovules. Also, similar changes might be induced by the entrance of the pollen tube, even though fertilization did not take place, as when parthenocarpic fruits appear. If mutations occur which can supply the proper conditions for these physico-chemical changes, then it is possible to explain the inheritance of the parthenogenetic character after it has once appeared. Physical changes in the cytoplasm surrounding the egg, as well as changes in the osmotic pressure, are considered as only theoretical explanations for parthenogenesis. If they should be a cause, Winkler asks, why should these changes occur in some flowers and not in others; and if they appear in all flowers, why should not parthenogenetic embryo formations occur in all?

One who is not acquainted with Winkler's and Blaringhem's papers should refer to the originals, as it is impossible to give all the subject matter proper treatment in a brief review. The complete bibliographies appended to these papers are also well worthy of reference.

TESTS FOR THE PRESENCE OF NATURAL PARTHENOGENESIS IN THE GENUS NICOTIANA

The writer obtained no viable seed in his numerous castration experiments with the exception of one doubtful case of *N. plumbaginifolia.* The seed of this exception was secured in a field experiment conducted on the heavy clay loam of western New York, used as a check on the experiments of Professor East made on the light sandy loam of eastern Massachusetts. Since the seed from this one capsule of *N. plumbaginifolia* was all that was obtained from ninety-eight emasculated blossoms of this species, it is reasonable to treat it as the result of an experimental error.

The method of testing for parthenogenesis in these field experiments consisted simply in emasculating and covering the flowers. Both paper sacks and cotton batting were used to protect the stigmas from self or cross-pollination. When the latter covering was used the anthers were removed with the assistance of a small wire hook which minimized the injury to the corolla and the cotton wad was then fastened over the end of the corolla tube with the aid of a rubber band. The supposed advantage of the cotton batting was that it would interfere less with the photosynthesis processes, than the paper sack, as it excludes much less air and sunlight. The seed of *N. plumbaginifolia* was obtained from a capsule covered with the cotton batting; otherwise, no definite results were noted in favor of either covering. As the heavy rains and strong winds will break off the capsules covered with cotton, it is advisable to enclose them with netting sacks.

The extent of these emasculation experiments of Professor East and myself in which not a single seed was produced outside of the capsule of *N. plumbaginifolia* already noted, is already seen by referring to Table I.

Mrs. R. H. Thomas was much more fortunate in her emasculation work, as she obtained fertile seed with no apparent difficulty. Why parthenogenetic tobacco seed should develop so readily in England and so rarely, if ever, in the eastern part of the United States is difficult to understand. The explanation may be found in the differences of the soils and the climatic conditions of the two places, but this assumption is improbable. It seems more likely that new buds which escaped notice were developed in the course of her experiments. This explanation of these divergent results is very probable, as adventitious buds appear for several weeks after the formation of the first buds. Both self-fertilized and parthenogenetic blossoms produce offspring true to the mother species; and consequently an error, if it did occur, could not be detected.

TABLE I

FIELD CASTRATION EXPERIMENT

Species	Mass.			N. Y.		
	No. Buds	Treatment	No. Seed	No. Buds	Treatment	No. Seed
N. alata var. *grandiflora*	14	Emas. and covered	0		Emas. and covered	
N. attenuata				17	Emas. and covered	0
N. Bigelovii	12	Emas. and covered	0			
N. Forgetiana	20	Emas. and covered	0			
N. glutinosa	8	Emas. and covered	0			
N. Langsdorffii	12	Emas. and covered	0	54	Emas. and covered	0
N. Langsdorffii var. *grandiflora*	8	Emas. and covered	0	87	Emas. and covered	0
N. longiflora	16	Emas. and covered	0	45	Emas. and covered	0
N. paniculata	21	Emas. and covered	0			
N. plumbaginifolia	11	Emas. and covered	0	98	Emas. and covered	Several (1 capsule)
N. quadrivalvis	14	Emas. and covered	0			
N. rustica var. *brazilica*	14	Emas. and covered	0	16	Emas. and covered	0
N. rustica var. *humilis*	20	Emas. and covered	0	113	Emas. and covered	0
N. rustica var. *texana*	12	Emas. and covered	0			
N. suaveolens	10	Emas. and covered	0	13	Emas. and covered	0
N. tabacum (broadleaf)	10	Emas. and covered	0	11	Emas. and covered	0
N. tabacum (calyciflora)				83	Emas. and covered	0
N. tabacum (fasciated)	14	Emas. and covered	0			
N. tabacum (Havana)	28	Emas. and covered	0			
N. tabacum (Sumatra)	16	Emas. and covered	0	74	Emas. and covered	0
N. tabacum var. *fruticosa*				77	Emas. and covered	0
N. tabacum var. *macrophylla purpurea*				33		

EXPERIMENTS ON THE ARTIFICIAL PRODUCTION OF APOMICTIC SEED IN THE GENUS NICOTIANA

For the simplification of the following subject matter, the experimental procedures used in the attempted production of parthenogenetic seed have been divided into four classes, namely, the effects of foreign pollen, of mutilation, of fumigation, and of injections.

The Effects of Foreign Pollen

Gärtner (Burbidge, 1877), while making species crosses, obtained seed in a few cases which produced plants true to the maternal species and also true hybrids. Mrs. R. H. Thomas (1909) and Professor E. M. East have also observed the same phenomenon in their work. Professor East's results were as follows:

Seed was obtained which produced plants like the mother species and also true hybrids, from crosses *N. paniculata*[4] × *N. alata* var. *grandiflora*, *N. rustica* × *N. tabacum*, and *N. tabacum* × *N. Bigelovii;* seed which produced plants like the mother species and no true hybrids, from crosses *N. paniculata* × *N. Langsdorffii*, *N. paniculata* × *N. longiflora*, *N. paniculata* × *N. Forgetiana*, and *N. Bigelovii* × *N. sylvestris;* and seed which produced no true hybrids on one occasion but did produce true hybrids on other occasions, from cross *N. tabacum* var. *lancifolia* × *N. alata* var. *grandiflora*. These crosses gave per capsule from one to twenty-five good seeds that produced plants true to the mother parent, and many angular and undeveloped seed that produced very few hybrids. In the cases where no hybrids were produced, abortive seeds—probably hybrid in character —were present.

These seeds, true to the mother species, are thought by Professor East to be due to adventitious embryos arising from the tissue of the nucellus, for no case of seed formation after simple castration occurred in some hundreds of experiments, nor did seed giving maternal plants arise in any but wide species crosses giving sterile or nearly sterile progeny. If such be the case, parthenogenesis did not occur in these crosses.

Pollen grains of certain species in the plant kingdom are known to be capable of instigating the development of parthenocarpic fruits and of polyembryonic seed of foreign species, but whether they can cause the parthenogenetic development of ovules is still a question; even though varieties of *Vitis vinifera* have been noted by Millardet (1901) as giving only *Vitis vinifera* progeny, when pollinated by *Ampelopsis hederacea*. Examples of the parthenocarpic fruits, however, are common. The writer, while attempting to cross the tomato with the Jerusalem Cherry (*Solanum Pseudo-capsicum*) obtained parthenocarpic tomato fruits, but no fruit of any kind developed when the reciprocal cross was made. Parthenocarpic Seckel pear fruits were also produced by the application of Yellow Transparent apple pollen. In the crosses between *Nicotiana* species already mentioned, seed true to the mother parent was produced; but as in the case of the *Vitis vinifera,* there is no positive proof of a parthenogenetic development. What stimulatory effect is imparted by the pollen grain must be due either to an irritation caused by the entrance of the pollen tube or to the exudation of a "growth enzyme."

---

[4] The authorities for the specific names of the *Nicotiana* species used in these experiments are given on p. 23.

THE EFFECTS OF MUTILATION

The floral and axial organs of the plants were mutilated by emasculation, by the removal of the anthers, by decapitation, by the removal of both the stigmas and anthers, and by burning various portions of young buds, with the object of upsetting the normal functional processes in such a way as to incite the parthenogenetic development of seed. To simple emasculation and decapitation were added several modifications. Emasculated buds were covered with both paper bags and celluloid covers, but no advantages in favor of either covering could be detected. The decapitated buds were covered with the same two coverings, and in addition buds were left uncovered, but no differences in the results of these three methods were noted. Theoretically, the buds provided with the greatest amount of light and air should be favored in their development, but in this particular case, the results did not permit one to draw conclusions, since only negative results were obtained. Since capsules of *N. tabacum* were found to develop from pollinated flowers as well under the paper bags as under the celluloid covers, the latter covering was soon discarded. The advantages of the paper bags are, first, they cover a great many buds and, second, they are put on and removed very easily.

Clusters of buds that had been emasculated as well as those that had been decapitated were also ringed a few inches below the buds. The operation was performed with the hope that the food stored above the injury would upset the natural equilibrium of nutrition in such a way as to cause the development of the ovules. In these ringing experiments only negative results were obtained, although Ewert found that injuries to gooseberry branches favored the development of parthenocarpic fruits.

Neither the tickling of *N. tabacum* buds, varying in size from small to large, with a camel's hair brush every half hour for five consecutive hours, nor the cutting of the bases of *N. suaveolens* and *N. commutata* buds, with the point of a scalpel, gave results. Professor East has, however, produced a slight swelling in the capsules, but no seeds, by occasionally tickling the buds of the following species with a sharp-pointed instrument—*N. tabacum* (vars. fasciated, Sumatra, broadleaf, and Havana), *N. alata, N. Bigelovii, N. Forgetiana, N. glutinosa, N. Langsdorffii, N. Langsdorffii* var. *grandiflora, N. longiflora, N. paniculata, N. plumbaginifolia, N. quadrivalvis, N. rustica* (vars. *humilis, brazilica,* and *texana*).

Stimulation was also attempted, as already noted, by burning or rather singeing buds varying in development from very young to nearly mature, with a heated platinum wire. The hot wire was applied to various portions of the buds, namely, to the base, to the top of the ovary, the stigma, and to both the stigma and the ovary. When the pistils were not injured, the blossoms were covered with bags, but covering was not considered essential when the pistils were made functionless. *N. Langsdorffi* var. *grandiflora* and *N. plumbaginifolia* gave no results, but one capsule of *N. tabacum* produced fifty-six apparently normal seeds—none of which germinated after a period of several months' rest. The stage of maturity and the parts burned of each bud were not recorded and therefore the condition and exact treatment of this particular bud are unknown.

As a check on the uncovered decapitated pistils,[5] pollen from the same and other varieties was applied directly to the cut surface of the styles; in addition to pollen, cane-sugar solutions varying from 25 per cent. to 50 per cent. in strength,[6] stigmatic fluids, and in one instance nectar taken from the base of buds, were also applied. If the shortened pistils could be fertilized, it was thought that certain impossible crosses, as *N. alata* × *N. Forgetiana* and *Mirabilis Jalapa* × *M. longiflora* might be made, providing the difficulty existed in the extreme length of the styles. In one case, the applied stigmatic fluid and the pollen grains were taken from the same species. This precaution was used, as it was thought that the stigmatic fluid of one species might contain an enzyme or an inhibiting substance which would prevent the germination of foreign pollen grains. This supposition was supported by the growth of pollen grains in stigmatic fluids placed within Van Tieghem cells. For instance, the *N. glauca* pollen grains germinated and made good growth in the stigmatic fluid taken from *N. glauca* plants, while *N. suaveolens* pollen grains did not extend their pollen tubes in the stigmatic fluid taken from *N. Forgetiana*. If the tissue of the style contains an inhibiting agent, also, the germination of pollen grains on the cut style would be of no benefit. (This supposition may explain the negative results.[7])

---

[5] Ewert (1909) quotes Gärtner who states that Henschel obtained seven ripe fertile seed from six blossoms of *Salvia sclarea* whose pistils had been destroyed, and four abortive seeds from three capsules of *Polemonium gracile* whose pistils had also been destroyed.

[6] A 33⅓ per cent. strength was used in the later work, as the pollen grains of *N. glauca, N. longiflora* and *N. tabacum* germinated readily and made good growth in this solution.

[7] The presence of one or more inhibiting agents might be used to explain the failure of grafts between plant species, for they may act like the antibodies, produced in animals by the transference of the blood of one species to that of another, and cause death.

Whether the pollen tubes in these experiments reached the ovules is not known, but probably not, since no fertile seed was produced. The production of numerous seed normal in appearance indicates, however, either that the pollen tubes must have stimulated the nucellus tissue in some way, or that normal seed development was started but not finished, for no seed of any kind was produced in the decapitated blossoms where pollen grains were not applied.

The total abortive seed produced by the pollination of the decapitated styles included two from *N. tabacum* where the stubs were covered with 50 per cent. cane sugar solution and self-pollinated, four from the same species where the stubs were covered with stigmatic fluid and self-pollinated, twenty-seven from *N. paniculata* where the stubs were covered with stigmatic fluid and self-pollinated, and fourteen from *N. tabacum* where *N. Forgetiana* pollen and no fluid was applied.

In connection with the decapitation experiments, an experiment on the grafting of pistils[8] was conducted. One hypothesis for the non-crossing of certain species, as has already been mentioned, is the extraordinary length of the style. By removing a portion of the style and grafting the stigma end of a pistil of either the same or another species to the stub, the style was shortened from one to one and a half inches. Immediately after grafting, the stigmas were pollinated. From one of the five grafted *N. tabacum* blossoms was produced one abortive seed. The development of this one seed may or may not have been due to the penetration of one or more pollen tubes, as in the cases where pollen grains were applied directly to the decapitated pistils.

---

[8] The grafting technique is simple, nevertheless, the operation is difficult, owing to the small size of the styles. A light splinter was first attached to the base of the style by means of collodion, then the upper portion of the style was removed with a sharp knife. The end of the pistil to be grafted on the stub was cut off at the same angle and placed on the stub and made fast with the collodion.

MUTILATION EXPERIMENTS—FORCING HOUSE

TABLE II

Species	No. Clusters	No. Buds	Treatment	Stig. Fluid	Pollen	No. Seed	Remarks
N. alata var. *grandiflora*	2		Decap.	Self	*N. Forgetiana*	0	
N. alata var. *grandiflora*	1		Decap.	Self	*N. Sandaræ*	0	
N. alata var. *grandiflora*	2		Decap.	Self	Self	0	
N. alata var. *grandiflora*	2		Decap.	$33\frac{1}{3}$ per cent. sugar	*N. Forgetiana*	0	
N. alata var. *grandiflora*	2		Decap.	$33\frac{1}{3}$ per cent. sugar	*N. Langsdorffii*	0	
N. alata var. *grandiflora*	1		Decap.	$33\frac{1}{3}$ per cent. sugar	*N. Sandaræ*	0	
N. alata var. *grandiflora*	1		Decap.	$33\frac{1}{3}$ per cent. sugar	Self	0	
N. Forgetiana	1		Emas. and covered			0	
N. Forgetiana	1		Decap.	*N. Langsdorffii*	*N. Langsdorffii*	0	
N. glauca	3	5	Emas. and covered			0	
N. glauca	2		Decap.			0	
N. glauca	1		Decap. and bagged			0	
N. glauca		3	Hot pt. wire and emas.			0	Singed stigmas.
N. Langsdorffii		5	Decap.	Self	*N. Forgetiana*	0	
N. Langsdorffii	1		Decap.	$33\frac{1}{3}$ per cent. sugar	*N. Forgetiana*	0	
N. Langsdorffii	2		Hot pt. wire and emas.			0	Singed base of buds.
N. Langsdorffii	1		Cut and emas.			0	Cut base of buds with scalpel point.
N. paniculata	4	12	Emas. and bagged			1	Seed abortive.
N. paniculata	5	5	Decap. and bagged			0	
N. paniculata		3	Decap.	Self	Self	27	Seed abortive.
N. paniculata	2		Decap.	25 per cent. sugar	*N. Tabacum*	0	
N. paniculata	4		Hot pt. wire and emas.			0	Singed stigmas.
N. plumbaginifolia	2		Hot pt. wire and emas.			0	Singed base of buds.

TABLE II (*Continued*)

Species	No. Clusters	No. Buds	Treatment	Stig. Fluid	Pollen	No. Seed	Remarks
N. Sandarae	1		Decap.			0	
N. Sandarae	1		Decap.	Self	*N. Forgetiana*	0	
N. suaveolens		3	Decap.	Self	*N. Forgetiana*	0	
N. suaveolens	1		Cut and emas.			0	Cut base of buds with scalpel point.
N. tabacum	5	12	Decap. and covered			0	
N. tabacum	2		Decap. and bagged	0	*N. Forgetiana*	14	Seed contained in one locule.
N. tabacum	3	28	Decap. and bagged	0	Self	6	Three seeds in one capsule and one seed in other capsules.
N. tabacum	14	10	Emas. and covered			0	
N. tabacum	1	15	Emas. and ringed			0	
N. tabacum		8	Emas. and tickled			0	
N. tabacum	1		Decap. and grafted		Self	1	
N. tabacum	2	2	Decap. and ringed			0	
N. tabacum	1	1	Decap.	$33\frac{1}{3}$ per cent. sugar	*N. Forgetiana*	0	
N. tabacum	1	1	Decap.	50 per cent. sugar	*N. glauca*	0	
N. tabacum	1	2	Decap.	50 per cent. sugar	Self	2	Seed found in one capsule.
N. tabacum	1	1	Decap.	Nectar	Self	0	
N. tabacum		14	Hot pt. wire and emas.			56	Singed stigmas. Seed borne in one capsule.
N. tabacum	1	4	Hot pt. wire and emas.			0	Singed both stigmas and ovaries.

The mutilation experiments all proved to be valueless in the production of fertile seed; nevertheless, they were interesting, since they were the only methods, except where actual crosses were made and where chloroform gas was used, which caused any seed development.

(See Table II—Mutilation Experiments.)

EFFECTS OF FUMIGATION

Several species, the names of which are listed in Table III, were exposed before the plants had reached the flowering stage to gases given off by acetone, carbon tetrachloride, chloroform, ether, ethyl acetate, ethyl bromide, ethyl chloride, ethyl iodide, and formaldehyde. As in the previous experiments, the buds were emasculated and bagged. The object of this experiment, as of the one on mutilation of the plants, was to endeavor to upset the normal development of the floral organs in such a way as to cause the production of seed without the aid of fertilization.

The methods used in conducting this experiment were simple. Plants, growing in six-inch pots, were fumigated approximately one seventh of a cubic foot when drawn in at the top. The bags were closed either around the stems which had been previously surrounded with cotton batting or about the top of the pots, the method of treatment depending on the height of the plants. When everything was in readiness for fumigation, the gas was set free by the opening of the vial which was glued to the interior of the bag. Though the seams and the bottoms of the bags were sealed by melted paraffine, the retention of all the gas was not expected. A sufficient quantity was present, however, when acetone and formaldehyde were used, for the foliage of the plants, treated with these gases, to become noticeably injured.

TABLE III

FUMIGATION EXPERIMENTS—FORCING HOUSE

Species	Ht. Plant, In.	Liquid	C.c. per Cu. Ft.	Hrs. Exposed	No. Seed	Remarks
N. alata var. *grandiflora*...	3	Ethyl acetate	8	24	0	Leaves drooped, three capsules developed.
N. alata var. *grandiflora*...	1½	Ethyl acetate	12	24	0	Leaves drooped.
N. Bigelovii.............	4	Acetone	12	40	0	Several leaves injured.
N. Bigelovii.............	2¼	CCl_4	12	40	0	Slight injury.
Dewey's Sport No. 1......	5	Ethyl acetate	4	43	0	No injury.
Dewey's Sport No. 1......	9¾	Ethyl acetate	4	72	0	No injury, six capsules developed.
Dewey's Sport No. 1......	4¼	Ethyl acetate	6	43	0	No injury.
Dewey's Sport No. 1......	9¾	Ethyl acetate	6	72	0	No injury, three capsules developed.
Dewey's Sport No. 1......	5	Chloroform	2	43	0	No injury.
Dewey's Sport No. 1......	12¼	Chloroform	2	72	0	One capsule had six locules, six capsules developed.
Dewey's Sport No. 1......	4	Chloroform	4	43	0	No injury.
Dewey's Sport No. 1......	9⅝	Chloroform	4	72	0	No injury, one capsule developed.
Dewey's Sport No. 1......	6	Formaldehyde	4	43	0	
Dewey's Sport No. 1......	13½	Formaldehyde	4	72	0	Five capsules developed.
Dewey's Sport No. 1......	3¾	CCl_4	4	43	0	No injury.
Dewey's Sport No. 1......	9⅛	CCl_4	4	72	0	No injury, four capsules developed.
Dewey's Sport No. 1......	5½	CCl_4	6	43	0	No injury.
Dewey's Sport No. 1......	11¼	CCl_4	6	72	0	No injury, five capsules developed.
N. Forgetiana...........	1½	Formaldehyde	8	72	0	
N. longiflora............		Ethyl chloride	12	24	0	Four capsules developed.
N. longiflora............	Sessile	Ethyl iodide	12	24	0	
N. longiflora............	Sessile	Ethyl iodide	12	24	0	Two capsules developed.
N. longiflora............	2¾	Ethyl acetate	12	24	0	Two capsules developed.
N. longiflora............	Sessile	Ethyl acetate	12	24	0	Four capsules developed.
N. paniculata...........	4½	Ethyl bromide	2	22	0	No injury.
N. paniculata...........	5	Ethyl bromide	4	22	0	No injury.
N. paniculata...........		Ethyl bromide	6	20	0	Cover a bell-jar—not a paper bag.
N. paniculata...........	6¾	Ethyl bromide	8	72	0	No injury.
N. paniculata...........	6¼	Ethyl bromide	12	72	0	No injury, seven capsules developed.
N. paniculata...........	6	Formaldehyde	4	20	0	
N. paniculata...........	7	Formaldehyde	2	20	0	
N. paniculata...........	5½	Acetone	2	22	0	Slight injury to foliage.
N. paniculata...........	7	Acetone	4	22	0	No injury to foliage.
N. paniculata...........	10½	Chloroform	1	22	2	No injury, one capsule developed.
N. paniculata...........	10	Chloroform	2	22	0	No injury.
N. paniculata...........	11	Ether	4	22	0	No injury.
N. plumbaginifolia........	Short	Ether	12	24	0	
N. plumbaginifolia........	Short	Ether	12	24	0	
N. plumbaginifolia........	10½	Ethyl iodide	8	24	0	
N. plumbaginifolia........	14½	Ethyl iodide	8	24	0	
N. plumbaginifolia........	1½	Ethyl bromide	12	40	0	One capsule developed.
N. quadrivalvis..........	8¼	Ethyl bromide	12	24	0	No injury, one capsule developed.

TABLE III (*Continued*)

Species	Ht. Plant, In.	Liquid	C.c. per Cu. Ft.	Hrs. Exposed	No. Seed	Remarks
N. quadrivalvis.	$9\frac{1}{2}$	Ethyl bromide	12	24	0	No injury, two capsules developed.
N. quadrivalvis.	8	Ethyl bromide	8	24	0	No injury, two capsules developed.
N. quadrivalvis.	10	Ethyl bromide	8	24	0	No injury.
N. quadrivalvis.	7	Ethyl chloride	12	24	0	Three capsules developed.
N. quadrivalvis.	6	Ethyl chloride	12	24	0	Three capsules developed.
N. quadrivalvis.	9	CCl_4	4	22	0	No injury.
N. quadrivalvis.	12	CCl_4	2	22	0	No injury.
N. rustica var. *texana*.	$6\frac{1}{4}$	Acetone	4	43	0	No apparent injury.
N. rustica var. *texana*.	$20\frac{1}{8}$	Acetone	4	72	0	Terminal growth injured, four capsules developed.
N. rustica var. *texana*.	9	Acetone	6	43	0	Terminal leaves, slightly injured.
N. rustica var. *texana*.	$21\frac{1}{4}$	Acetone	6	72	0	One leaf injured, four capsules developed.
N. rustica var. *texana*.	5	Ethyl bromide	4	43	0	No injury.
N. rustica var. *texana*.	17	Ethyl bromide	4	72	0	No injury, seven capsules developed.
N. rustica var. *texana*.	$5\frac{3}{4}$	Ethyl bromide	6	43	0	One leaf slightly injured.
N. rustica var. *texana*.	$17\frac{1}{2}$	Ethyl bromide	6	72	0	One terminal blossom leafy, six capsules developed.
N. rustica var. *texana*.	7	Ether	4	43	0	No injury.
N. rustica var. *texana*.	$15\frac{3}{4}$	Ether	4	72	0	Terminal bud injured and produced leafy blossom. Eight capsules developed.
N. rustica var. *texana*.	$6\frac{3}{4}$	Ether	6	43	0	No injury.
N. rustica var. *texana*.	18	Ether	6	72	0	No injury, thirteen capsules developed.
N. Sandaræ		Chloroform	8	24	0	No injury, three capsules developed.
N. Sandaræ		Chloroform	12	24	0	No injury, one capsule developed.
N. sylvestris.	Sessile	Chloroform	12	24	0	Leaves (outer) turned yellowish after two days.
N. sylvestris.	Sessile	Chloroform	12	24	0	
N. sylvestris.	Sessile	Ether	8	24	0	
N. sylvestris.	Sessile	Ether	8	24	0	
N. sylvestris.	Sessile	CCl_4	12	24	0	No injury.
N. sylvestris.	Sessile	CCl_4	12	24	0	No injury.
N. tabacum var. *fruticosa* . .	11	Ether	8	72	0	No injury.
N. tabacum var. *fruticosa* . .	$5\frac{1}{2}$	Ether	12	72	0	No injury.
N. tabacum var. *fruticosa* . .	$7\frac{1}{4}$	CCl_4	8	72	0	No injury.
N. tabacum var. *fruticosa* . .	$5\frac{3}{8}$	CCl_4	12	72	0	No injury.
N. trigonophylla.	5	Ethyl bromide	12	40	0	
N. trigonophylla.	$1\frac{1}{2}$	Acetone	12	40	0	Leaves injured.
N. trigonophylla.	$3\frac{1}{2}$	CCl_4	12	40	0	No injury.

Untreated plants of all of the above species were held as checks on the results of each test. A *N. rustica* var. *texana* plant produced one leafy terminal blossom, otherwise, all the plants were normal.

A *N. paniculata* plant treated with chloroform gave two abortive seeds, but none of the other species produced a seed. *N. rustica* var. *texana,* however, after two exposures to acetone vapor underwent very marked morphological changes in the structure of the terminal blossoms, both of the main and of the lateral stems. In other words, the most exposed buds suffered the greatest injury. As the ether, ethyl bromide, and check treatments produced one blossom apiece which was similarly affected, and no other species, even though treated with acetone, was injured in the same way, indicates that the *N. rustica* var. *texana* floral parts are somewhat unstable. This opinion is substantiated by Penzig who in his *Pflanzen-Teratologie* cites observations where *N. rustica* blossoms have been modified to such a degree that the petals have turned green and where five blossoms have been compressed into a common calyx. Perhaps the presence of a small amount of chlorophyll in the greenish yellow corollas is an indication of a close relationship of the petalous to the leafy condition. Even though the *N. rustica* blossoms are easily modified, it is very evident that the acetone vapor caused a disturbance in the natural development of the floral organs, for the two treated plants were affected in the same way and degree. The calyxes, corollas and stamens were modified markedly, while the carpels and pistils and most of the stamens were usually normal in appearance. For instance, in some cases the calyxes were fused together and enlarged to such a size that they resembled distorted and crinkled leaves. One blossom had three sepals fused to the corolla and two sepals located one half inch below the base of the blossom. The lower two had a node as distinct as any leaf on the branch, and within their axis were borne two small buds, which lacked calyxes. One of the upper three sepals also bore a similar naked bud in its axis. It may be that in this case the acetone vapor stunted the branches in such a way that many latent buds were present in a very small space. The corollas in some cases were entirely replaced by small green leaves—smaller than the sepals—and in other cases they were partially replaced by leafy tissue. A few stamens had their filaments flattened and their anthers replaced by a small green leaf. These changes might be advanced, as an evidence of the evolutionary development of the floral organs, if the theory that these organs are simply modified leaves and that reversions are frequently caused by injuries were not already so well substantiated. Whether any mutations might have occurred in the progeny produced from these blossoms is unknown, as fertilization of the ovules was not attempted. No parthenogenetic seed was obtained from these injured blossoms, and this might have been expected, since leafy formations in the blossoms are generally accompanied by sterility.

EFFECTS OF LIQUID INJECTIONS

The forcing of liquids into the plants was performed with the same object in view as in the preceding experiments, viz., to endeavor to stimulate cell division and thus possibly produce unfertilized seed. To certain liquids has been ascribed the power of being able to cause mutations when injected into the buds of certain plants, but in this experiment all the injections were made directly into stems of plants, eight to twenty inches in height.

The apparatus used was simple. Glass capillary tubes were connected by rubber tubing to glass tubes, about 30 inches long and about one quarter inch in diameter, which contained the liquids. The rubber tubing permitted the stems to lengthen without disturbing the operations. The end of the capillary tube was inserted from one eighth inch to one quarter inch into the stem, the distance depending upon the diameter of the stems and 1 inch to 15 inches below the terminal bud. An application of collodion held the capillary tube in place and stopped all leakage. After having supported the tube, the pinchcock—previously fastened to the rubber tubing—was released and the liquid flowed into the stem as rapidly as it could be used by the plant. The injection was assisted by the weight of its own column, and, in the most cases, by the addition of a short column of mercury, suspended by the surface tension of the liquid. The use of the mercury required considerable care, for when the surface tension was overcome by a jar, the mercury sank to the bottom and plugged the capillary tubes.

The treated species were: *N. tabacum* var. *fruticosa, N. paniculata, N. Langsdorffi* var. *grandiflora, N. Langsdorffii, N. alata* var. *grandiflora, N. attenuata,* and *N. Sandaræ.*

The materials used for the injections are: Sodium phosphate, butyric and valeric acids, ethyl acetate, acetone, benzol, chloroform, formaldehyde, methyl blue, saffranin and thiazin. The last three are simply stains and were used to trace the course of the liquids. The coloring matter was found to follow the vascular bundles of the stems and the leaves for several inches, and yet the slightest trace was not discovered in the buds. Acetone, butyric, and valeric acids of .5 per cent. strength caused severe injury, formaldyhyde at 2 per cent. caused a slight injury to the foliage, but no other liquid caused a noticeable disturbance.

All the treated plants, as in the previous experiments, had at least one cluster of buds emasculated and bagged, but all to no purpose, since not even one abortive seed developed.

SUMMARY

1. Seed giving plants true to the maternal species in the F_1 generation accompanied by aborted seed probably hybrid in nature, was found when certain *Nicotiana* species were cross-fertilized. Hybrid plants and plants purely maternal were obtained from the same capsules in other crosses.

2. The capsules of several *Nicotiana* species were

caused to swell slightly by merely tickling them with a sharp-pointed instrument, but no seeds were produced.

3. Abortive seed probably without embryos was produced by singeing young buds with a hot platinum wire, by the exposure of young plants to chloroform gas, and by cutting away a portion of the pistil and pollinating the stub both with and without the accompaniment of a germinative fluid.

4. Abortive seed was produced by shortening the pistils of a flower and grafting the stigma end of another pistil on to the stub and pollinating the same.

5. The ringing of the branches below a cluster of buds did not assist in the production of seed.

6. No seed was produced by the simple methods of emasculation and decapitation of blossoms, except in one doubtful case of *N. plumbaginifolia.*

7. It is likely that an agent inhibitory to the growth of pollen grains is present in the stigmatic fluids of certain species of the genus *Nicotiana;* at least, the pollen grains of *N. suaveolens* did not germinate in *N. Forgetiana* stigmatic fluid when placed within a Van Tieghem cell.

8. The exposure of young *N. rustica* var. *texana* plants to acetone gas caused the transformation of the corollas and the stamens of most of the terminal flowers into leafy tissue; otherwise, except in the mentioned case of the chloroform, no results were secured by the use of anaesthetic and toxic gases.

9. The injection of chemicals into the stems of tobacco plants was valueless in the production of seed.

10. As no unquestionable case of parthenogenetic seed was produced in the several hundred trials, it seems very improbable that parthenogenesis exists in the genus *Nicotiana*—at least in the species tested. The seed obtained in the crosses which came true to the mother species is probably polyembryonic—the stimulus of development being imparted either by the penetrating pollen tubes or by a substance exuded from the same.

NICOTIANA SPECIES USED IN THE EXPERIMENTS

- *N. alata* Lk. & Otto var. *grandiflora* Comes.
- *N. attenuata* Torr.
- *N. Bigelovii* Wats.
- *Dewey's Sport* No. 1.
- *N. Forgetiana* Sand.
- *N. glauca* Grah.
- *N. glutinosa* L.
- *N. Langsdorffii* Weinm.
- *N. Langsdorffii* Weinm. var. *grandiflora* Comes.
- *N. longiflora* Cav.
- *N. paniculata* L.
- *N. plumbaginifolia* Viv.
- *N. quadrivalvis* Pursh.
- *N. rustica* L. var. *brazilica* Schrank.
- *N. rustica* L. var. *humilis* Schrank.
- *N. rustica* L. var. *texana* Comes.
- *N. Sandaræ* Hort. (hybrid).
- *N. suaveolens* Lehm.
- *N. sylvestris* Speg & Comes.
- *N. tabacum* (broadleaf).
- *N. tabacum* (calyciflora).
- *N. tabacum* (fasciated).
- *N. tabacum* (Havana).
- *N. tabacum* L. var. *fruticosa* Comes.
- *N. tabacum* var. *lancifolia* (W.) Comes.
- *N. tabacum* L. var. *macrophylla purpurea*.
- *N. tabacum* L. (Sumatra).
- *N. trigonophylla* Dun.

SELECTED BIBLIOGRAPHY

Bary, A. de (1878). Ueber apogame Farne und die Erscheinung der Apogamie im Allgemeinen. *Botan. Zeitung,* Bd. 36, 1878, p. 449.

Bateson, W. (1909). Mendel's Principles of Heredity. Cambridge, 1909, pp. 246–249.

Bernhardi (1839). Sur la formation des graines sans l'aide de la fécondation. *Ann. Sc. Nat. Bot.,* 2 sér., t. XII, p. 362.

Bitter, G. (1904). Parthenogenesis und Variabilität der *Bryonia dioica. Abh. d. Nat. Ver. zu Bremen,* Bd. XIII, 1904, pp. 99–107.

Blaringhem, L. (1907). Mutation et traumatismes. *Bull. scient. de la Fr. et de la Belg.,* t. XLI, pp. 1–248.

—— (1907). Production d'une variété nouvelle d'Epinards, *Spinacia oleracea* var. *polygama. C. R. Ac. Sc.,* Paris, t. CXLVII.

—— (1909). La Parthénogénèse des Plantes Supérieures, pp. 113–170.

Boveri, Th. (1889). Ein geschlechtlich erzeugter Organismus ohne mütterliche Eigenschaften. *Sitzungsber. d. Gesellsch. f. Morphol. u. Physiol. zu München,* Bd. 5, 1889, p. 73.

Braun, A. (1857). Ueber Parthenogenesis bei Pflanzen. *Abhandl. d. kgl. Akad. d. Wissensch. zu Berlin,* Phys. Kl., 1856, pp. 311–376.

Burbidge, F. W. (1877). The Propagation and Improvement of Cultivated Plants. Edinburgh and London, 1877, p. 543.

Camerarius, R. J. (1691 a.). Semina mori subventanea. *Ephemerid. Germ.,* Dec. II, Ann. IX, p. 212.

—— (1691 b.). Ova mercurialis subventanea. *Ephem. Germ.,* Dec. II, Ann. X, p. 90.

—— (1694). De Sexu plantarum epistola. *Ephem. Germ.,* Dec. III, Ann. III, p. 31. Voir traduction allemande par M. Mobius (*Ostwald's Klassiker,* No. 105).

Darwin, C. (1893). Variation of Animals and Plants under Domestication. Second edition, revised. London, Vol. II, 1893, p. 152.

Day, D. F. (1896). Parthenogenesis in *Thalictrum Fendleri*. *Bot. Gaz.*, Vol. 22, 1896, p. 241.

Delage, Y. (1899). Etudes sur la mérogonie. *Arch. de zoologie expérim. et gén.*, 3 sér., T. 7, 1899, p. 383.

Ewert, R. (1906). Blutenbiologie und Tragbarkeit unserer Obstbäume. *Landw. Jahrb.*, Bd. 35, 1906, pp. 259–287.

—— (1907). Die Parthenocarpie oder Jungfernfrüchtigkeit der Obstbäume und ihre Bedeutung für den Obstbau. Berlin, 1907.

—— (1909). Neuere Untersuchungen über Parthenokarpie bei Obstbäumen und einigen anderen fruchttragenden Gewächsen. *Landw. Jahrb.*, Bd. XXXVIII, 1909, pp. 767–839.

—— (1910). Parthenokarpie bei der Stachelbeere. *Ibid.*, Bd., XXXIX, 1910, pp. 463–470.

Farlow, W. G. (1874). An Asexual Growth from the Prothallus of *Pteris cretica*. *Quart. Jour. of Microsc. Sci.*, Vol. 14, 1874, pp. 266–271.

Farmer, J. B., and Digby, L. (1907). Studies in Apospory and Apogamy in Ferns. *Ann. of Bot.*, Vol. 21, 1907, pp. 161–199.

Focke, W. O. (1881). Pflanzen-Mischlinge. Berlin, 1881, pp. 271–286.

Ganong, W. F. (1898). On polyembryony and its Morphology in *Opuntia vulgaris*. *Bot. Gaz.*, Bd. 25, 1898, p. 221.

Gärtner, J. (1788). De fructibus et seminibus plantarum. Stuttgard, Bd. 1, 1788.

Gärtner, C. F. (1844). Versuche und Beobachtungen über die Befruchtungsorgane der vollkommneren Gewächse. Stuttgart, 1844.

—— (1849). Versuche und Beobachtungen über die Bastarderzeugung im Pflanzenreich. Stuttgart, 1849.

Gasparrini, G. (1846). Origine de l'embryon dans les graines des plantes phanérogames. *Ann. Sc. Nat. Bot.*, 3 sér., t. V, pp. 305–312.

Girou De Buzareingues (1828). La Génération. Paris, in–8°.

—— (1829). Expériences sur la génération des plantes. *Ann. Sc. Nat.*, sér. I, t. 16, pp. 140–143.

—— (1830). Expériences sur la génération des plantes. *Ann. Sc. Nat.*, sér. I, t. 19, pp. 297–305.

—— (1833). Expériences sur la génération des plantes. *Ann. Sc. Nat.*, sér. I, t. 30, pp. 398–410.

Goebel, K. (1900). Organography of Plants. English edition by Balfour, I. B., Oxford, Pt. 1, 1900.

Guérin, P. (1904). Les connaissances actuelles sur la fécondation chez les Phanérogames. Paris.

Hertwig, O. u. R. (1887). Experimentelle Studien am thierischen Ei. *Jen. Zeitschr. f. Naturwiss.*, Bd. 20, 1887, pp. 120 u. 477.

Jost (1907). Ueber die Selbsterilität einiger Blüten. *Bot. Ztg.*, Heft V u. VI, 1907.

Jost, L. (1907). Lectures on Plant Physiology. English translation by Gibson, H. J. Oxford, 1907.

Juel, O. (1898). Parthenogenesis bei *Antennaria alpina* (L.) R. Br. V. M. *Botan. Centralbl.*, 74, 1898, pp. 369–372.

—— (1900). Vergleichende Untersuchungen über typische und parthenogenetische Fortpflanzung bei der Gattung Antennaria. *Kgl. svenska Vetensk.-Akad. Handl.*, Bd. 33, No. 5, 1900, pp. 1–39.

Kirschner, O. (1900). Uber die kernlose Mispel. *Jahresh. d. Vereins. f. vaterl. Naturk. in Wurttemburg,* 1900.

—— (1905). Parthenogenesis bei Blütenpflanzen. *Ibid.*, Bd. 61, 1905, pp. liii–liv.

Lecoq (1827). Recherches sur la reproduction des végétaux. Clermont d'après de Candolle, A., Introduction à la Botanique, t. I, p. 549.

Massart, J. (1902). Sur la pollination sans fécondation. *Blu. der jard. botan. de l'état à Bruxelles,* Bd. 1, 1902, Fasc. 3.

Millardet, A. (1901). Note sur la fausse hybridization chez les Ampélidées. *Revue de Viticulture,* T. 16, 1901, pp. 677–680.

Müller-Thurgau (1898). Abhängigkeit der Ausbildung der Traubenbeeren und einiger anderer Früchte von der Entwickelung der Samen. *Landw. Jahrb. der Schweiz.*, 1898, pp. 155, 156.

Murbeck, Sv. (1901). Parthenogenetische Embryobildung in der Gattung Alchemilla. *Lunds Univ. Arsskrift,* Bd. 36, Afd. 2, No. 7, 1901.

—— (1904). Parthenogenesis bei den Gattungen Taraxacum und Hieracium. *Bot. Notiser,* 1904, p. 285.

Nathanson, A. (1900). Ueber Parthenogenesis bei Marsilia und ihre Abhängigkeit von der Temperatur. Ber. deutsch. *Bot. Gaz.*, Bd. 18, 1900, pp. 99–109.

Naudin, C. (1856). Observations relatives à la formation des graines sans le secours du pollen. *C. R. Ac. Sc. Paris,* t. XLIII, n° 10.

Nemec, B. (1902, 1903). Ueber ungeschlechtliche Kernverschmelzungen. I. II. III. Sitzungsber. d. kgl. böhm. *Gesellsch. d. Wissensch.*, 1902, No. LIX, 1903, No. XXVII und No. XLII.

Noll, F. (1902). Ueber Fruchtbildung ohne vorausgegangene Bestaübung (Partenocarpie) bei der Gurke. *Sitzungsber. d. Niederrhein. Gesellsch. f. Natur. u. Heilk. zu Bonn,* 1902, S.-A.

Ostenfeld, C. H. (1904). Zur Kenntnis der Apogamie in der Gattung Hieracium. *Ber. d. deutsch. bot. Gesellsch.*, Bd. XXII, 1904, p. 376.

—— (1906). Castration and Hybridization Experiments with some Species of *Hieracia. Botan. Tiddskr.*, Bd. 27, 1906, pp. 225–248.

—— u. Rosenberg, O. (1910). Studies concerning apogamy and hybridization of the *Hieracia* (translated). *Zeitschr. f. Induk. Abstam. u. Vererb.*, Bd. III, Heft IV, 1910.

Overton, J. B. (1902). Parthenogenesis in *Thalictrum purpurascens. Bot. Gaz.*, Vol. 33, 1902, pp. 363–375.

—— (1904). Ueber Parthenogenesis bei *Thalictrum purpurascens. Ber. d. deutsch. botan. Gesellsch.*, Bd. 22, 1904, pp. 274–283.

Penzig, O. (1894). Pflanzen-Teratologie. Genua, Bd. 2, 1894, p. 178.

Pfeffer, W. (1903). Physiology of Plants. English translation by Ewart, A. J., Oxford, Vol. II, 1903.

Rosenberg, O. (1906). Ueber die Embryobildung in der Gattung *Hieracium. Ber. d. deutsch. botan. Gesellsch.*, Bd. 24, 1906, pp. 157–161.

—— and Ostenfeld, C. H. (1907). Cytological Studies in Apogamy in *Hieracium. Botan. Tidsskrift,* Bd. 28, 1907, pp. 143–170.

Shaw, W. R. (1897). Parthenogenesis in *Marsilia. Bot. Gaz.*, Vol. 24, 1897, p. 114.

Smith, J. (1841). Notice of a Plant which Produces Seed Without Any Apparent Action of Pollen. *Transact. of the Linn. Soc. London,* Vol. 18, 1841, pp. 509–511.

Spallanzani (1785). Expériences pour servir à l'histoire de la génération des animaux et des plantes. Genève.

Strasburger, E. (1877). Ueber Befruchtung und Zelltheilung. Leipzig, 1877.

—— (1878). Ueber Polyembryonie. *Jen. Zeitschr. f. Naturwiss.,* Bd. 12. 1878, pp. 647–670.

—— (1904). Apogamie in Eualchemilla. *Jahr. f. wiss. Bot.,* Bd. XLI, 1905, pp. 88–164.

—— (1907). Apogamie bei Marsilia. *Flora,* Bd. XCVII, 1907, pp. 123–191.

—— (1909). Zeitpunkt der Bestimmung des Geschlechts, Apogamie, Parthenogenesis, und Reduktionsteilung. *Histol. Beiträge,* Heft VII, 1909.

Thomas, R. H. (1909). Parthenogenesis in *Nicotiana. Mendel Jour.,* No. 1, 1909, pp. 5–10.

Treub, M. (1902). L'organe femelle et l'embryogénèse dans le *Ficus hirta. Vahl. Ebenda,* 2 sér., T. 3, 1902, pp. 124–157.

Webber, H. J. (1905). Notes on *Citrus* Hybrids. *Am. Br. Assoc.,* Vol. 1, 1905, pp. 78–86.

Winkler, Hans (1908). Parthenogenesis und Apogamie in Pflanzenreiche. *Progr. rei bot.,* Bd. II, Heft 3, 1908, pp. 293-454.